PROJECT PROGRESS REPORT

PREPARED FOR THE ALASKA ENERGY AUTHORITY BY
THE ALASKA CENTER FOR ENERGY AND POWER

PROJECT TITLE: *Round 1:* Emerging Energy Technology Fund – Data Collection

REPORTING PERIOD: 4th Quarter 2014

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EETF Round 1 Projects

Project #003 – Alaska Division of Forestry, Biomass Reforestation

On October 16, 2014, Chris Pike and Erin Whitney of the Alaska Center for Energy and Power (ACEP) traveled to Palmer and Willow, Alaska, to visit several reforestation sites that were planted by the Alaska Division of Forestry (DoF). Jeff Graham, from the DoF, drove with Chris and Erin in a DoF truck to the sites. The sites are testbeds for determining the suitability of several varieties of poplar tree cuttings for future biomass projects in Alaska.

The project originally started in the summer of 2013. However, after an abnormally dry summer, the mortality percentage of the planted cuttings was extremely high. Cuttings were replanted in June of 2014, and the survival rate has been much better.

ACEP visited three planting sites off Willer Cash Road near Willow, Alaska, about a two-hour drive north of Anchorage. These sites are shown in Figure 1 and are identified as Willer Cash #1, #2, and #3.

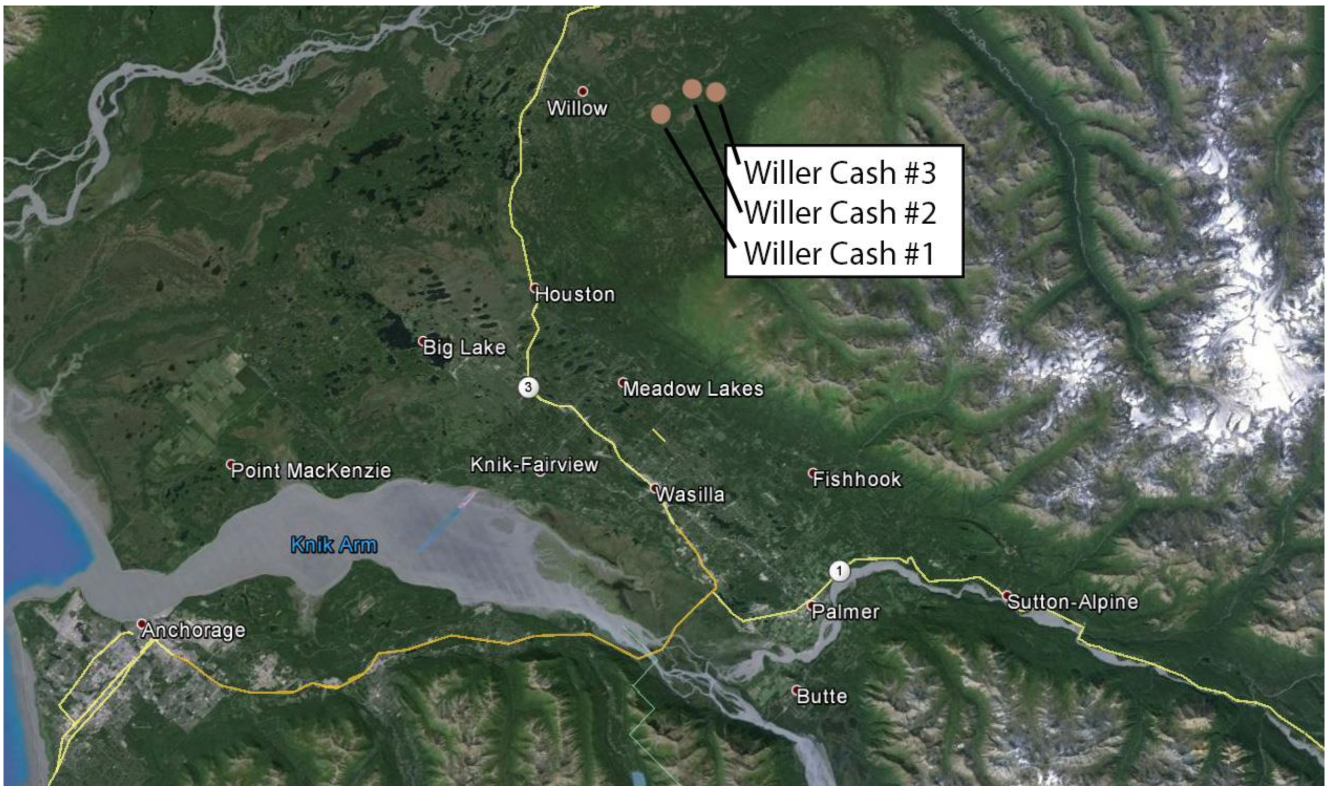

Figure 1: The three poplar study areas visited by ACEP staff.

The primary objectives of the site visit were to retrieve a Hobo data logger at one of the sites and observe planting survival and growth. Unfortunately, two other loggers had been eliminated from service in the other study area; one had been stolen, and a second was inoperable due to a gunshot hole.

Because of unusually dry weather and high mortality rates in 2013, each site was replanted in June of 2014 with four different varieties of poplar: (1) a hybrid variety from Canada, (2) a non-hybrid variety from Alberta, Canada, (3) a variety of Palmer, and (4) a variety from Delta Junction. Each variety has different genetic variations, and the goal was to determine which variety had the highest survival rate after being planted from cuttings.

Willer Cash #2 and #3 are timber logging sites where heavy equipment has been active. There is little to no undergrowth. Willer Cash #1 is a state sanctioned firewood cutting area. Due to the lack of heavy equipment and ground disturbance, there is significant undergrowth consisting of knee-high grasses and willow trees. Jeff indicated that the conditions at Willer Cash #1 have led to issues with small animals eating new growth shoots from the cuttings and, consequently, high mortality rates. He refers to this site as “abnormal” and wishes to drop it from the study.

The different poplar varieties were marked with different colored pin flags as detailed in Table 1. For each site, the percent survival and growth heights were measured.

Table 1. Flag colors marking different poplar varieties

Flag Color	Variety
Blue	Delta Native Poplar
Yellow	Hybrid Canada Poplar
Pink	Native Palmer Poplar
Orange	Non Hybridized Canada Poplar

According to Jeff, 1867 cuttings were planted in June of 2014. The survival rates as of September of 2014 are shown in Table 2. Next summer, data collection will be important to assess the survival rates through the winter.

Table 2. Poplar survival percentages

Variety	Percent Survival
Hybrid	85%
Alberta	73%
Palmer	39%
Delta	36%

The only surviving data logger was collected from the Willer Cash #3. The data was extracted for the time period between June 2013 and September 2014 with temperatures measured at four different depths ranging from the ground surface to 35 centimeters below ground level. The data is summarized in Figure 2. Unfortunately, since this is the only data logger with recoverable data, temperature and survivability comparisons between different sites cannot be made.

The temperatures generally trend as expected. The surface temperature sensor measures a wide variety of temperatures which are likely dependent on irradiance air temperature. It appears the temperatures measured by this sensor between November and June were less erratic, likely due to snow cover. Deeper buried sensors show that the ground froze and began to thaw in late May.

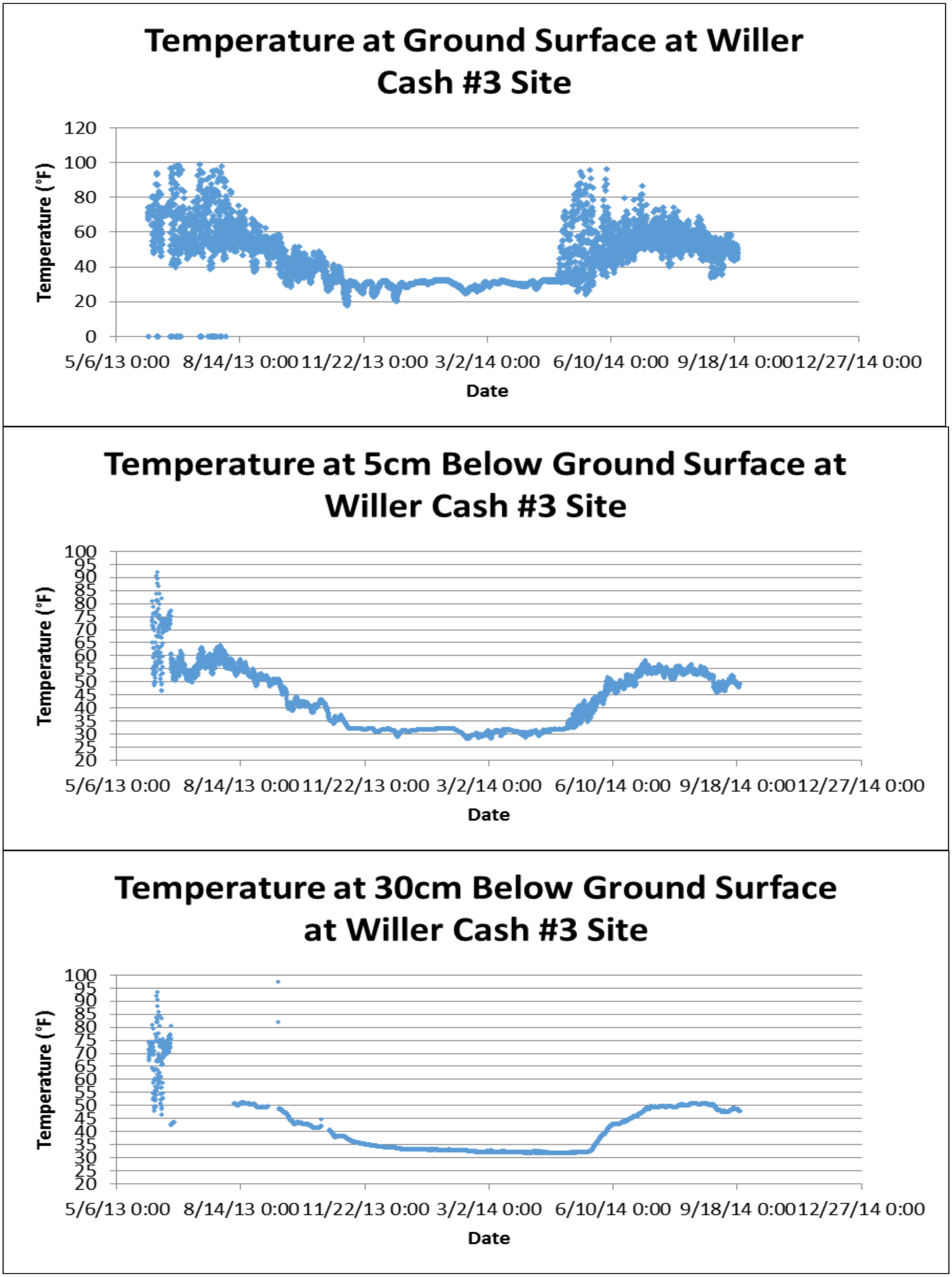

Figure 2: Temperature readings at Willer Cash #3

Figure 3: Erin Whitney of ACEP discusses the project with Jeff Graham of the Department of Forestry.

Figure 4: Pin flags marking poplar cuttings can be seen at one of the study sites.

Figure 5: A Hobo data logger is retrieved from the field. Once back at the ACEP lab, the year's worth of temperature data was downloaded and analyzed.

As stated previously, data collection next summer will be important to assess survival rates through the winter.   ACEP anticipates limited involvement with this project until that time.

Project #006 – Arctic Sun, Arctic Thermal Shutters and Doors

Arctic Sun continues to provide weekly data transfers to ACEP, and aliasing issues have been resolved. These data detail the performance of their shutters and doors. These data show that recorded AC current correlates well with outside temperatures and will allow for the heat loss through the shutters to be quantified. An example plot is shown in Figure 6. ACEP will continue to monitor data collection activities during the upcoming quarter.

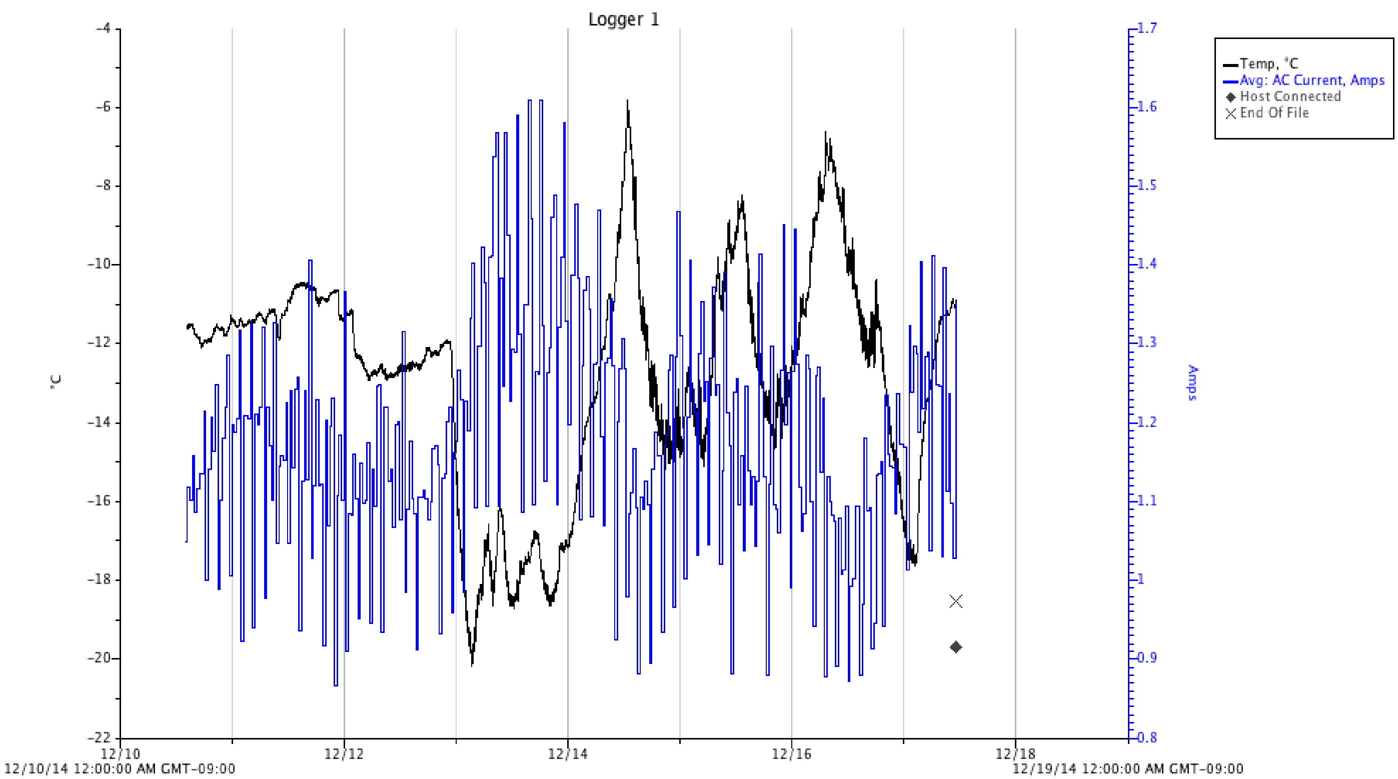

Figure 6: Sample Arctic Sun data showing AC current and outside temperature for shutter installation

Project #009 – Genesis – Ultra-Efficient Generators and Diesel-Electric Propulsion

ACEP has not received an update from Genesis and will send an addendum to this report when it does.

Project #026 – Cold Climate Housing Research Center (CCHRC), Ground Source Heat Pump (GSHP)

The ground source heat pump installed at the Cold Climate Housing Research Center continues to function as expected. As reported previously, the heat pump continues to function with a coefficient of performance (COP) between 3 and 4. Figure 7 shows recent COP and ground temperature data from the fall and winter of 2014. As expected, the ground temperature has dropped as the ground has frozen. The COP of the heat pump has subtly trended downwards as the ground temperature has dropped, but the COP has remained above 3.

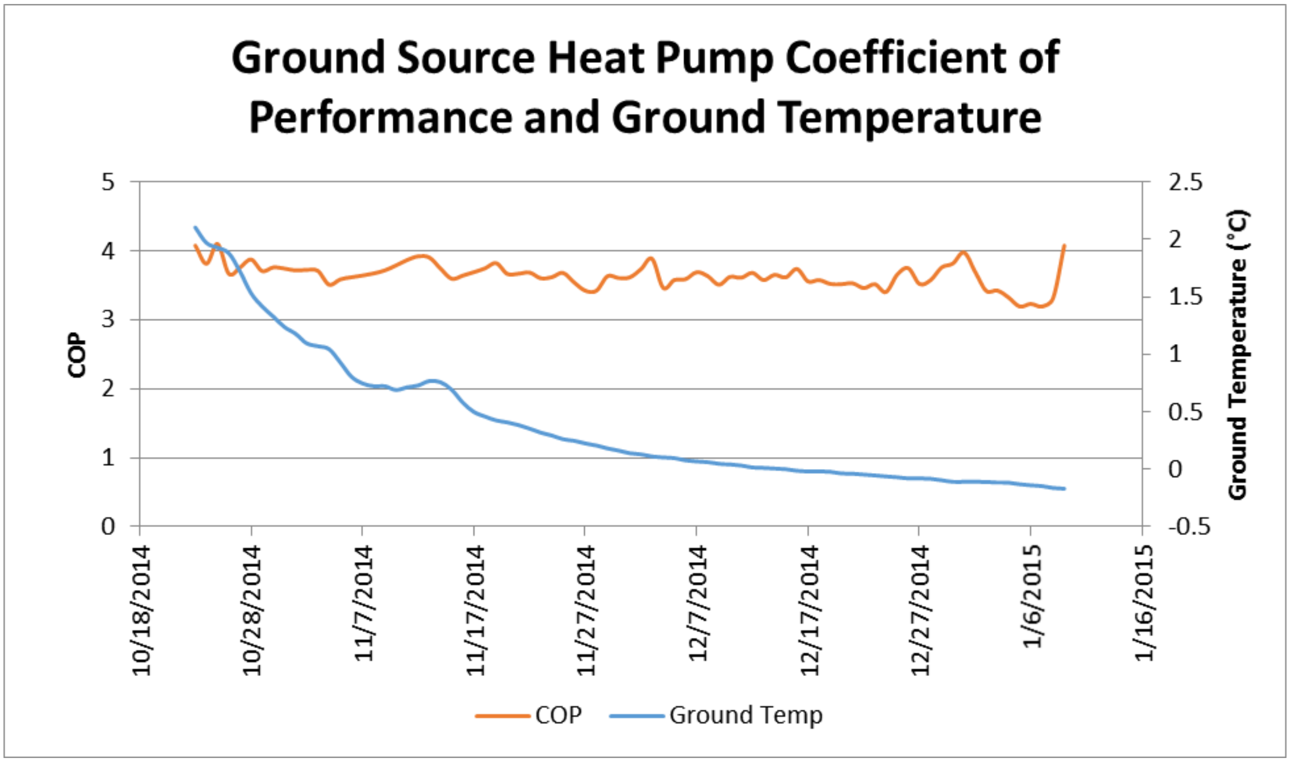

Figure 7. The graph shows the average hourly COP in relationship to the ground temperature.

A more detailed analysis of the ground temperatures is presented in this report. Figure 8 shows the arrangement of ground temperature sensors and surface treatments of grass, sand, and gravel. The glycol ground loops, responsible for transferring ground heat to the heat pumps, are buried 9 feet (2.7 meter) beneath the ground surface. This depth is the temperature measurement depth for subsequent plots in this section. Each loop and temperature sensor string is positioned beneath a different ground covering. The west ground loop ("West Loop Temp String") is below the gravel surface treatment, the center ground loop ("Center Loop Temp String") is below the sand treatment, and the east ground loop ("East Loop Temp String") is below the grass. In addition, temperature sensor strings are located on the far west and east ends of the installation, outside the glycol loop areas. They are labeled as "West Temp String" and "East Temp String" in Figure 8.

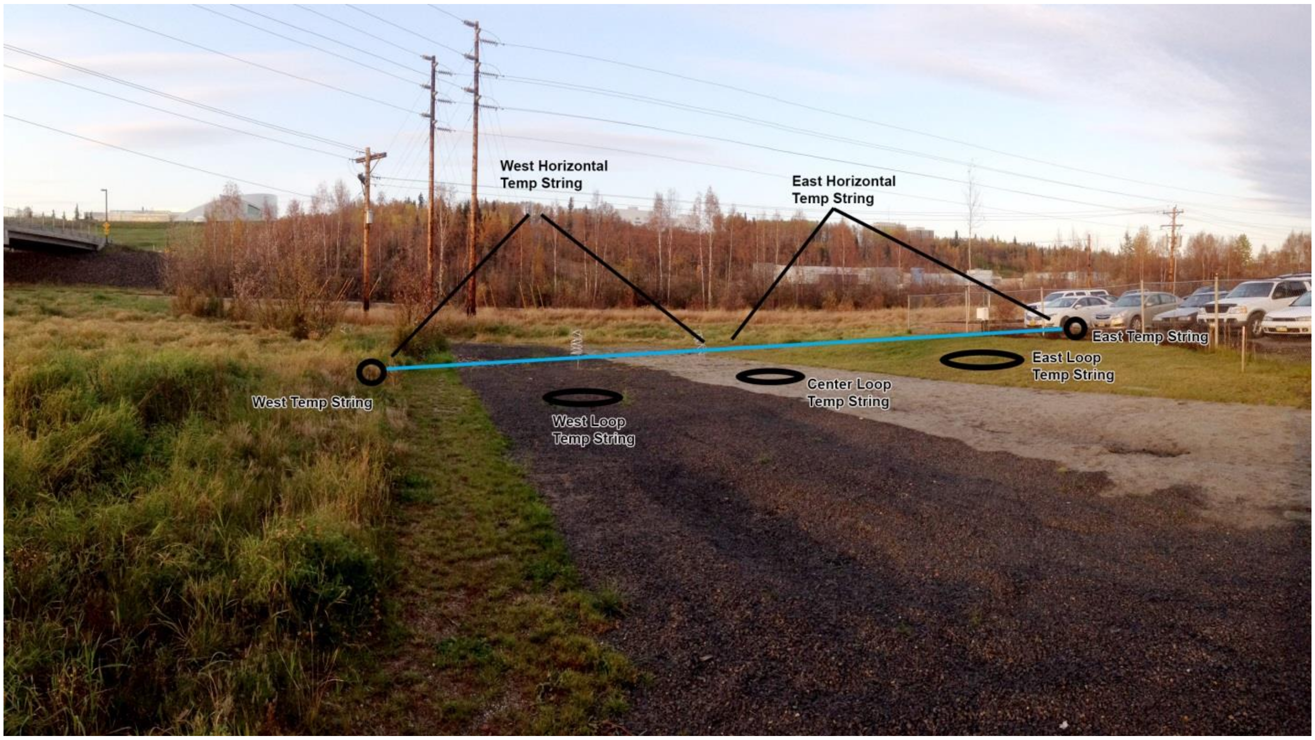

Figure 8: The picture shows the location of the glycol ground loops as well as the different strings of temperature sensors.

Figure 9 shows soil temperatures measured at the glycol loop depth. The center and east loop temperatures appear to be nearly identical while the temperatures measured below the west ground loop are abnormally high. ACEP will consult with the CCHRC to review the west loop temperatures. The temperatures around the center and east loops appear relatively stable and vary as expected, with the ground warming in the summer and fall, and cooling to near freezing during the winter.

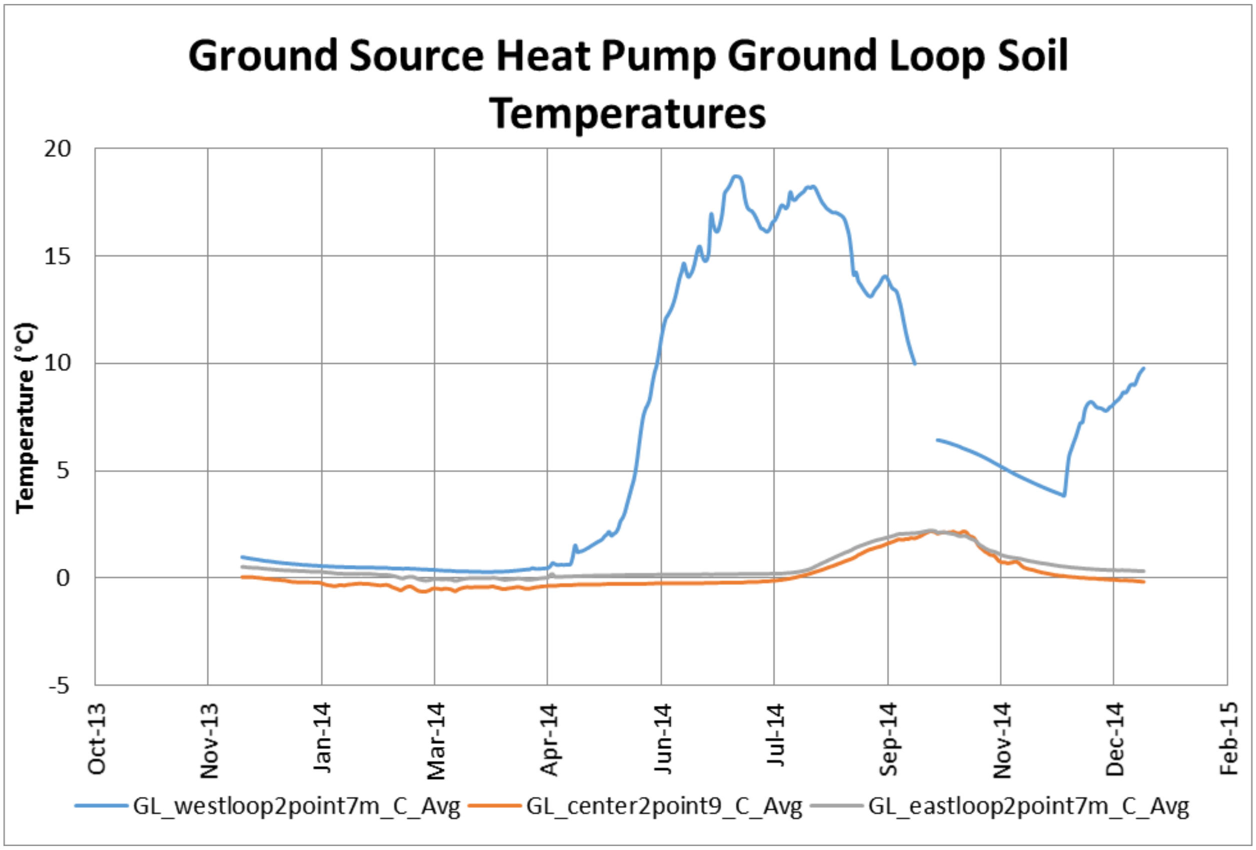

Figure 9: The temperatures beneath each type of ground cover near the heat pump glycol loops. The west loop temperature measurements appear to be erroneously high.

Temperatures were also compared under the loops and in the temperature strings outside the glycol loop areas. The goal of this comparison was to assess temperature differences in areas with and without the heat pump glycol loops. In Figure 10, the likely erroneous west loop string sensors make a comparison with the west string sensor impossible. The west string temperatures are as expected, with high soil temperatures in September, and soil temperatures nearing the freezing mark during winter.

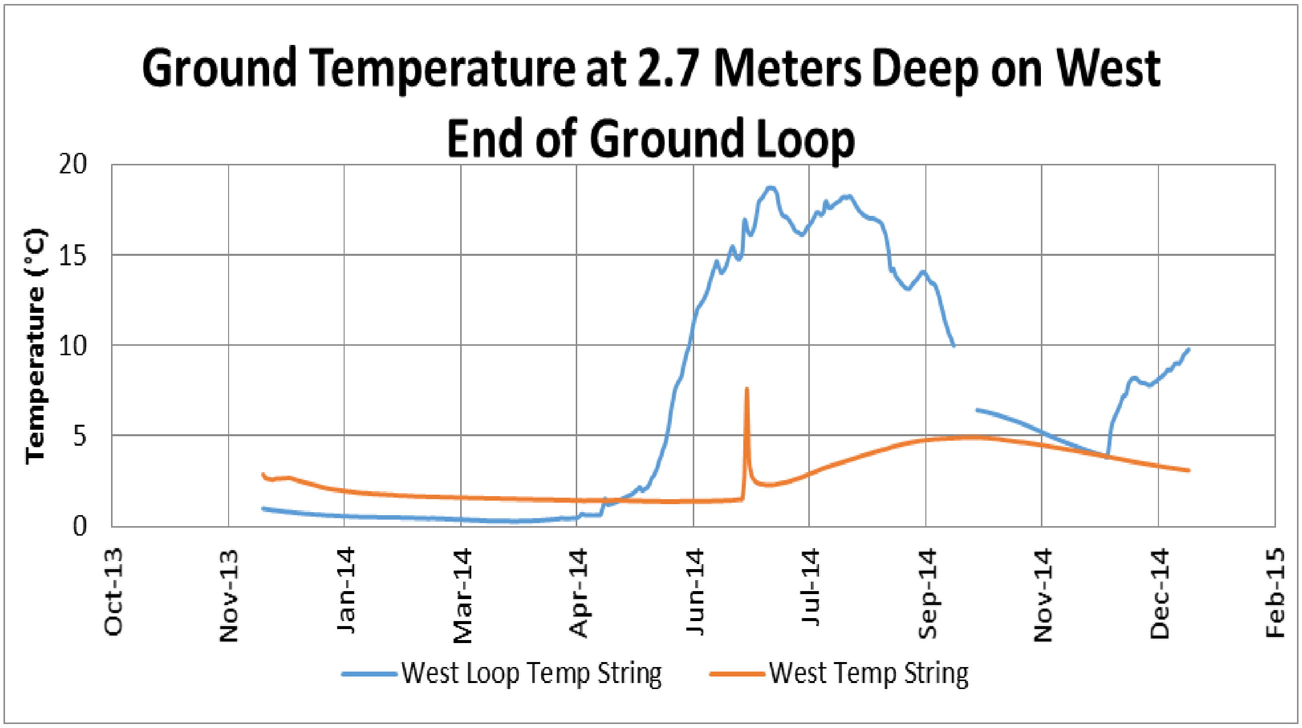

Figure 10: West side temperatures near the glycol loop and outside of the glycol loop are shown in the graph above. Unfortunately the west loop temp string temperature appears to be erroneously high.

The sensors on the east end of the temperature strings allow for the comparison of the eastern temperatures outside of and near the glycol loop. These data are detailed in Figure 11. The east loop temperature is recorded near the glycol loop, and it is noticeably cooler than the east temp string. Still, the east temp string is measured under the paved parking lot (Figure 8) that likely absorbs more heat in the summer sun. Despite the lower temperatures of the east loop string, the temperatures stabilize near freezing and do not appear to be cause for concern at this point.

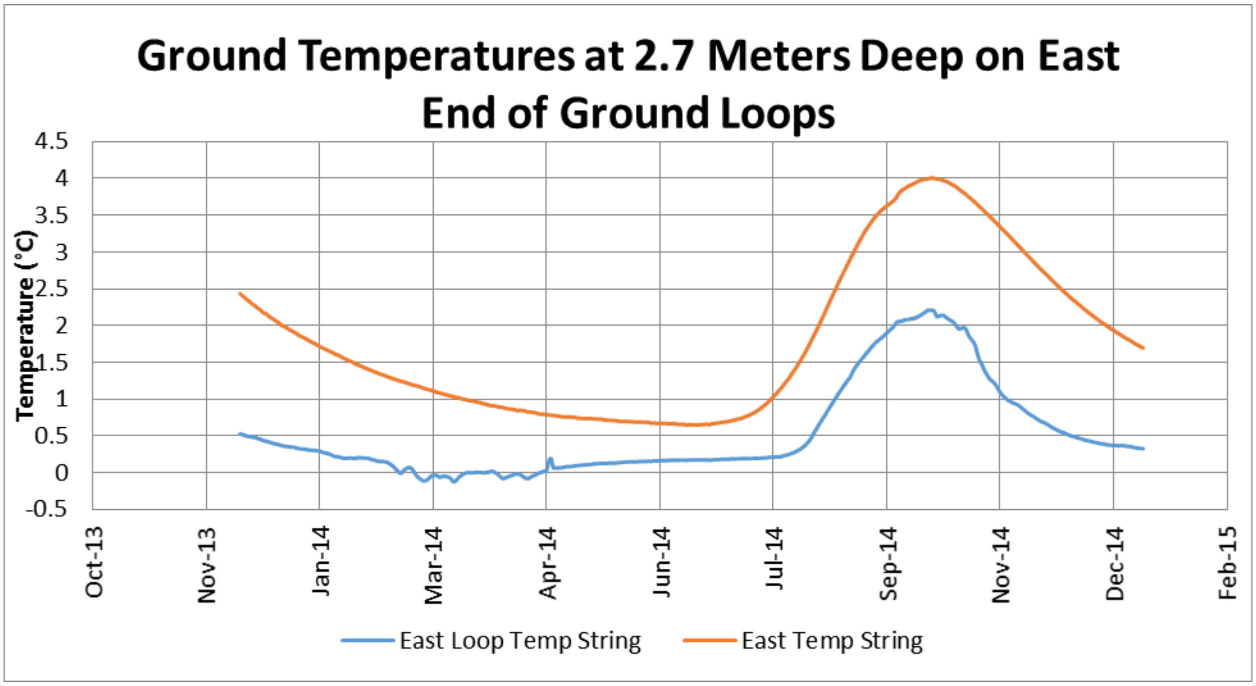

Figure 11: The eastside temperatures are shown in the graph above. The curves show soil temperatures near the glycol loop and outside of the glycol loop.

Data collection will continue in the next quarter.

Project #028 – University of Alaska Fairbanks (UAF), Organic Rankine Cycle (ORC)

The UAF Organic Rankin Cycle team has experienced numerous problems with its test apparatus and instrumentation and has been consulting with ACEP for help. Baseline testing was conducted at atmospheric pressure without problem. However, attempts to test at elevated pressure demonstrated that the apparatus leaked. Upon investigation, it was found that the plumbing was a hodgepodge of mismatched fittings and tubing. ACEP replaced all fittings and valves with Swagelok, and the leak rate was significantly reduced. Further testing revealed a leak from within the apparatus. As of late December 2014, this final leak was repaired, and instrumentation issues were resolved. The ORC team expects to begin testing in earnest this quarter.

Activities next quarter include continued close monitoring towards the goal of data collection.

Project #029 – University of Alaska Fairbanks, Exhaust Thimble

The exhaust thimble team has been stalled by a lack of subzero weather. The period of January 5-7, 2015, provided the first real cold of the season, and the thimble team was able to complete basic testing of the 2-inch thimble. Subsequently, the weather has again become uncooperative. Statistically speaking, January and February are the coldest months of the year and the team remains optimistic that testing will be completed in that time frame.

Project #035 – Altaeros, Airborne Wind Turbine

Project activities this quarter have been minimal. ACEP continues to monitor project status.

Project #037- Oceana, Hydrokinetics

ACEP has corresponded with Oceana and awaits receipt of data after an intensive field season.

Project #043 – Ocean Renewable Power Corporation (ORPC), Hydrokinetics

During the fourth quarter in 2014, ORPC released one-second power production data that were recorded at Igiugig during the summer of 2014. Unfortunately, due to glitches with their flow velocity meters, flow velocity measurements were not recorded. Flow velocity is critical to assess the turbine performance.

Researchers from the University of Washington (UW) were conducting bathymetry research related to the hydrokinetic studies and recorded detailed flow velocity data around the ORPC turbine. ACEP has been working closely with UW to get these flow data and will present the flow velocity data and turbine power production in the next quarterly report.

Project #058 – Boschma Research Inc. (BRI), Hydrokinetics

Despite efforts to secure flow velocity data from BRI and the University of Washington (UW), no velocity data was obtained. During email exchanges with Jim Boschma, he indicated that UW had measured a flow velocity of 2.5 m/s in the vicinity of their turbine. This velocity was used to calculate the previously reported performance curve, which is reproduced in Figure 12 and shows maximum power production at 50 rpm.

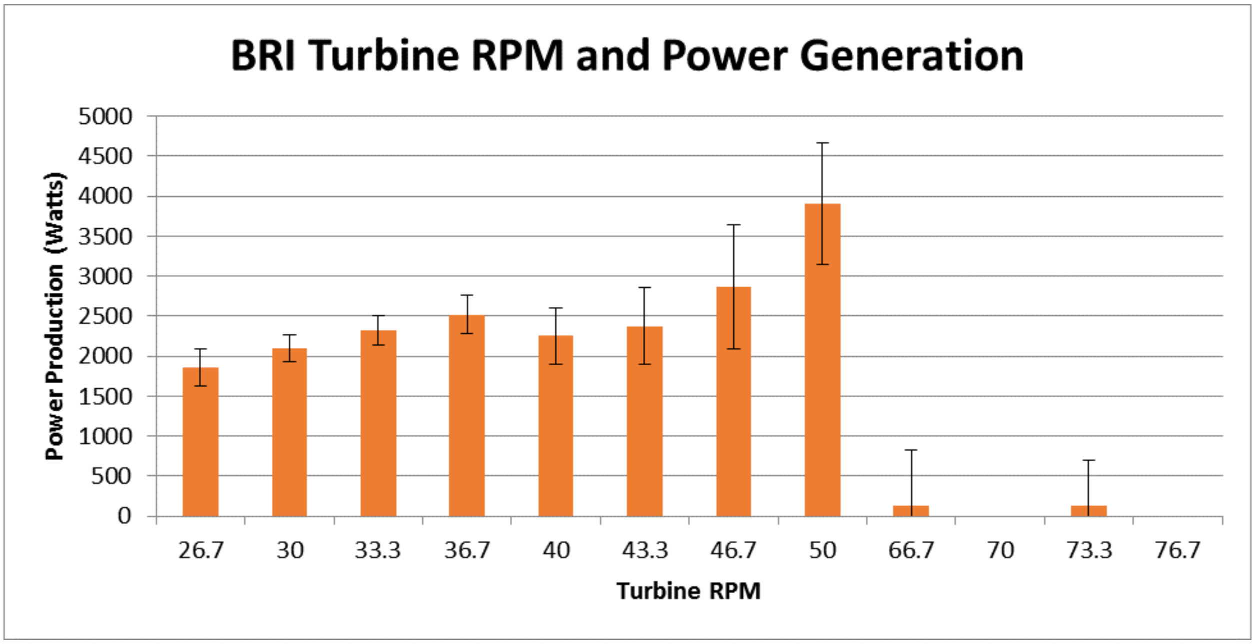

Figure 12. The average power production is graphed with the turbine RPM rates.

Currently there is dialogue within the hydrokinetic research community about the best way to derive a power curve during in-river hydrokinetic testing. To calculate power curves for tidal and wind turbines, the maximum power generated at each window of flow velocity is used. Unfortunately, during in-river testing, the flow velocity is confined to a very small window and remains rather constant. The International Electrotechnical Commission is trying to establish standards for calculating power curves for in-river hydrokinetic turbines, but at this time none exist.

The turbine specification data below is taken from the January 2014 BRI progress report to AEA.

Swept area = Front of Venturi Duct = 1.7 m x 4.45 m = 7.56 m^2
Turbine diameter = 1.4 m
Turbine circumference = 4.39 m

Given the 2.5 m/s flow velocity, the hydrokinetic power in the water is calculated using the power equation:

$P = 1/2pAV^3$
$p = 1000\ kg/m^3$
$v = 2.5\ m/s$
$A = 7.56\ m^2$

Power in this cross sectional area at 2.5 m/s = 59000 Watts.

Detailed performance data is shown in Figure 13 which compares the coefficient of performance (Cp) and turbine tip speed ratio at a velocity of 2.5 m/s. Cp is defined as the quotient of the power extracted by the turbine and the power of the river current. It's essentially a measure of efficiency. The tip speed ratio is a ratio of the blade tip speed to the current speed. One can observe in this graph that a wide range of Cp values occur at each tip speed ratio that is measured. The graph shows significant data for the tip speed ratios between 0.75 and 1.5. Outside of this range, the limited number of data points does not allow for any firm conclusions to be made.

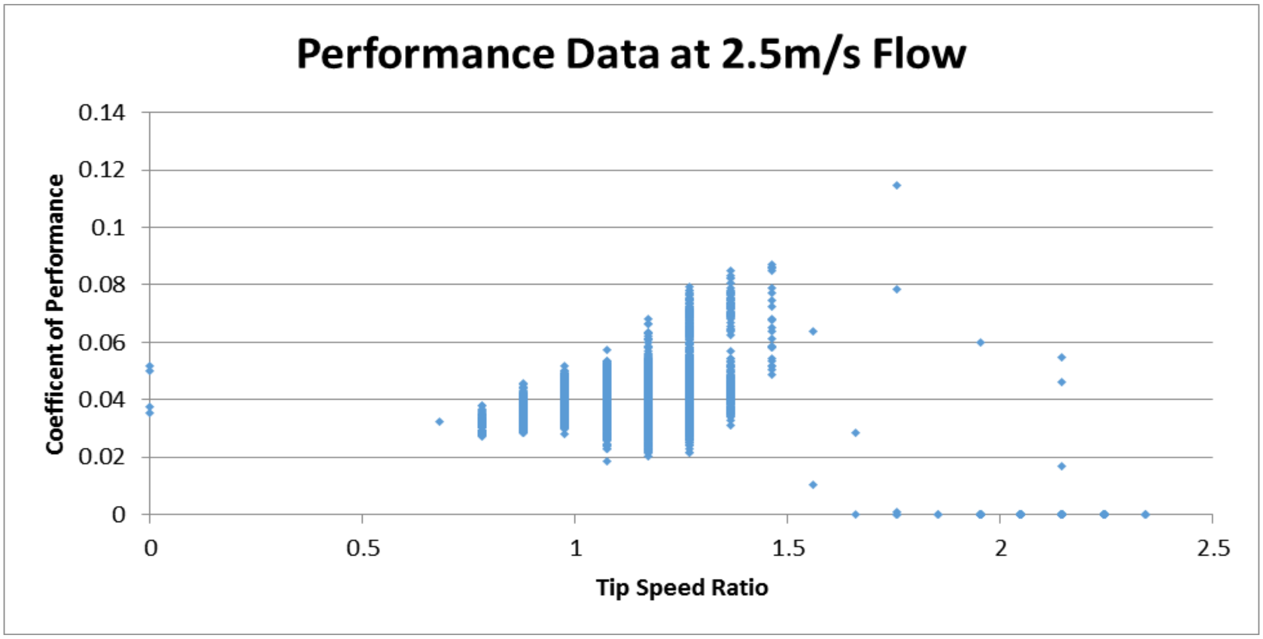

Figure 13: The scatter plot above shows the coefficient of performance graphed against the tip speed ratio.

In Figure 14, the performance data from Figure 13 is presented as Cp averages and maximums at each tip speed ratio. The maximum Cp of .087 (about 8.7% efficient) was reached at a tip speed ratio of 1.5. If further turbine testing is desired, it should be done in a way that allows the turbine to be tested at various flow velocities. This would allow the performance curve shown below to be developed for a range of flow rates. From this information, a power curve can be derived which would show the expected power output at different flow velocities.

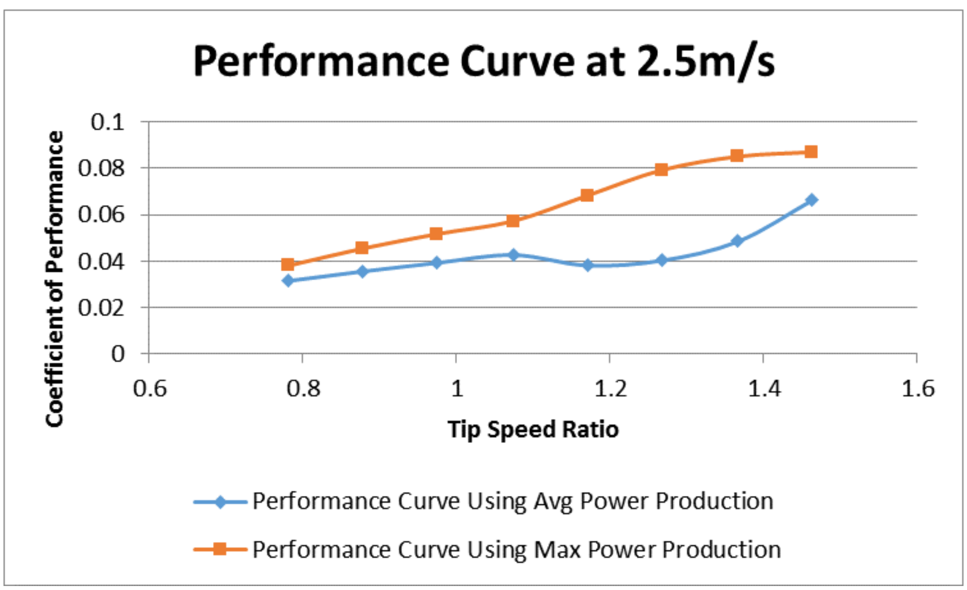

Figure 14: Average and maximum coefficients of performance as a function of tip speed ratio

Project #045 – Hatch, Flywheel

During November 2014, Hatch conducted extensive shakedown testing at ACEP's energy technology facility. The testing team collected volumes of high quality 120 Hz data. These data sets detail the flywheel's performance during a plethora of tests and contain information detailing the flywheel's response to perturbations. An example plot of the data is shown in Figure 15. Full testing is underway, and the data should provide an excellent characterization of the Hatch system.

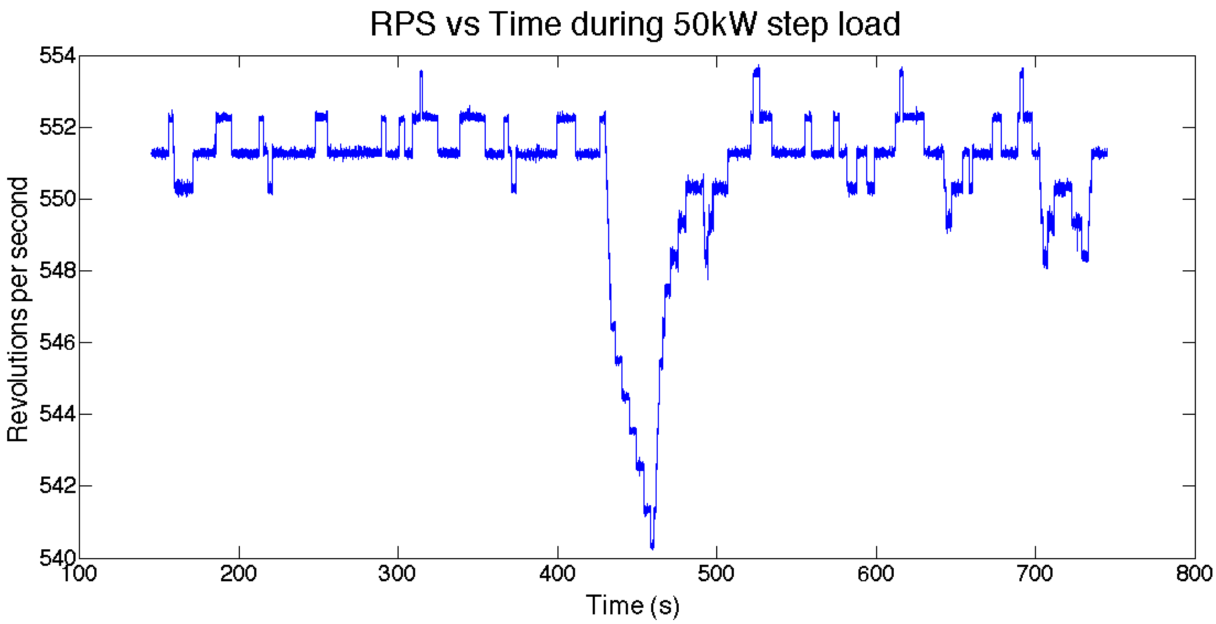

Figure 15: Revolutions per second as a function of time during a 50kW step load

Project #061 – Marsh Creek, Various Speed Diesel-Electric Generation

Marsh creek is reconfiguring their flux drive system and anticipates a final round of testing in late January or early February. ACEP intends to be onsite for a portion of this testing. Of particular interest will be data gathered during the "gear shift."

Project #049 – Intelligent Energy Systems (IES), Self-Regulated Grid &
Project #051 – Intelligent Energy Systems (IES), Wind-Diesel-Battery Hybrid System

IES provided one-second data for November 2014 as well as a report detailing operation during this time period. Of note, wind provided 31% of the electrical demand during that month, and there were eight diesel-off events. This report further detailed operational issues such as turbines and generators that were down for maintenance and negatively affected the system's performance.

The data set provided was missing approximately 3.7% of the records for one of the diesel generators. No explanation was given for the missing data, but the absence was explicitly noted. Of concern is the lack of data regarding power quality. The report stated, "Automatic transfer between the diesel generator and BESS and back again occurred 8 times during this period without any significant power quality issues," but no quantitative basis is provided for this statement. Additionally, no information was provided regarding the state of health of the battery system. ACEP will be conducting a site visit in the next quarter and continuing efforts towards meaningful data collection.